MICROPLASMA DISCHARGES EXсITED BY a PLASMA FLOW ON CONSTRUCTIONAL MetalS

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The interaction of a pulsed plasma flow with a negatively biased (~100−450 V) metal surface partially covered with a ~1-μm-thick dielectric film results in the excitation of microplasma discharges (MPDs) (microarcs) at the film edge [1, 2]. Under the action of the plasma ion flow, the outer surface of the film acquires a positive electric potential with respect to the metal, due to which a strong electric field of about several MV/cm arises at the film edge. This field initiates surface breakdowns and local explosive emission from the metal, which results in the excitation of MPDs with a plasma density of ~1020 cm−3 and temperature of ~0.5−1 eV [3, 4]. The high pressure (~107 Pa) of the plasma and metal vapor heated to ~5000 K above the melted metal surface at the MPD locations leads to the formation of microcraters on the metal surface. Since MPDs evaporate the dielectric film, the area covered by the film gradually shrinks and, after several plasma pulses, the entire metal surface turns out to be remelted and cleaned of the film. As a result, a strong microrelief in the form of overlapping craters is produced on the metal surface.

In our experiments, MPDs on metal samples were excited by a pulsed plasma flow with a density of ~1012−1013 cm−3 and an electron temperature of *Te* ≈ 10 eV. The parallelepiped samples with a total surface area of 2−3 cm2 were made of VT1 titanium, V95 aluminum alloy, or Steel 45. The dielectric (oxide) film was deposited on the sample surface by heating in open air [1, 2]. Under the action of the ~20-μs-long plasma flow, MPDs were excited at the border of the area covered with the dielectric film. The MPDs continued to burn for ~20 ms (while the negative voltage was being applied to the sample), i.e., long after the initiating plasma pulse had terminated. After ~10 plasma pulses, the sample was completely cleaned of the film and its entire surface acquired a strong microrelief. At MPD currents of 100−600 A, the maximum microrelief height on all four faces of the sample was in the range of 2–18 μm. The treated and untreated samples were subject to standard tribological tests [5]. The results of tribological tests of steel 45 samples shows an increase in the allowable pressure from 3 MPa (for samples without MPD treatment) to 25 MPa (for samples treated by MPDs at a current of 400 A). The values of the wear intensity do not exceed 5 × 10–9 at the microrelief tops and 0.7 × 10–9 at the protrusion bases, which nearly coincides with the corresponding values for steel 45 samples exposed to standard thermal hardening. The allowable pressure is about twice as high as that for steel 45 after standard thermal hardening up to the hardness of 40–45 HRC.

The phenomenon of a microplasma discharge on a metal surface in a plasma flow opens wide prospects for the development of wear resistant materials that can find application in industry, as well as in orthopaedics and stomatology, because the interaction of MPDs with metals and alloys substantially increases their microhardness and wear resistance due to the formation of a strong microrelief on their surfaces.

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References

1. V.A. Ivanov, A.S. Sakharov, M.E. Konyzhev, Plasma Phys. Rep. 34 (2008) 150.
2. V.A. Ivanov, A.S. Sakharov, M.E. Konyzhev, Usp. Prikl. Fiz. 1 (2013) 697.
3. V.A. Ivanov, B. Jüttner, H. Pursch, IEEE Trans. Plasma Sci. 13 (1985) 334.
4. A.S. Sakharov, V.A. Ivanov, Usp. Prikl. Fiz. 4 (2016) 150.
5. V.A. Ivanov, M.E. Konyzhev, L.I. Kuksenova, V.G. Lapteva, I.A. Khrennikova, J. of Machinery Manufacture Reliability 44 (2015) 384.